Stock Assessments: The Science of Fisheries

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PRESENTATION OUTLINE

- Mandate and Goals
- Stock Assessment Methods
  - Importance of Data Collection
  - Limitations of Stock Assessment
- The Foundations for Fisheries Management
- Settings OY, ABC and Rebuilding rates

MANDATE from MSFCMA

- National Standard 1:
  - Conservation and management measures shall *prevent overfishing* while achieving…the *optimum yield* from each fishery...
- Fishery Management Plans must:
  - specify objective and measurable criteria for identifying when a fishery is overfished
    - how the criteria were determined
    - relationship of criteria to reproductive potential
- Thus, comprehensive and accurate scientific information is required.

Stock Assessments

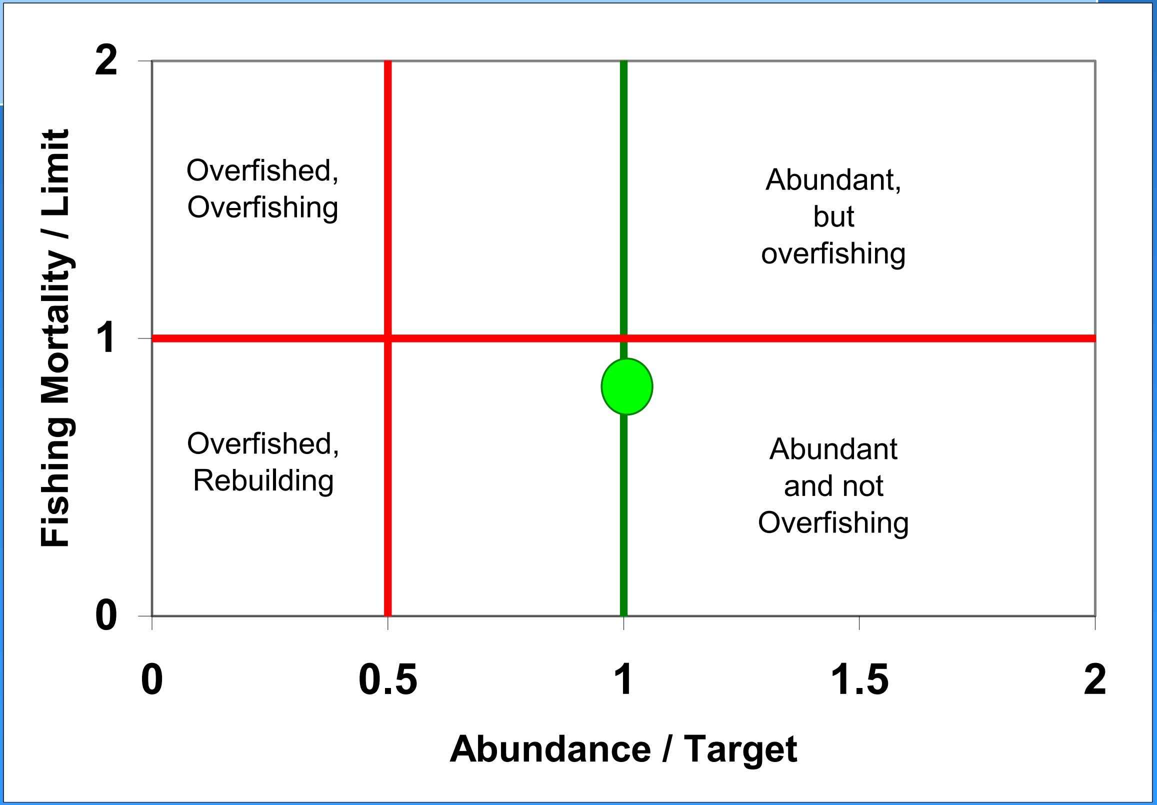
- Measure Reproductive Potential of a Stock of Fish
  - Historical and Current Level
  - Target and Limit Level
  - Forecast Future with Different Harvest Strategies

Stock Assessment Defined

- Collecting, analyzing, and reporting demographic information for the purpose of determining the effects of fishing on fish populations
- Key Concepts / Jargon
  - Stock; Population; Unit
  - Abundance; Biomass
  - Reproductive Potential; Spawning Biomass
  - Recruitment; Yearclass; Cohort
  - Fishery
  - Fishing mortality (F); Exploitation Rate

Retrospective Questions

- Stock Status
  - Did overfishing occur last year?
  - Is abundance below the overfished limit?

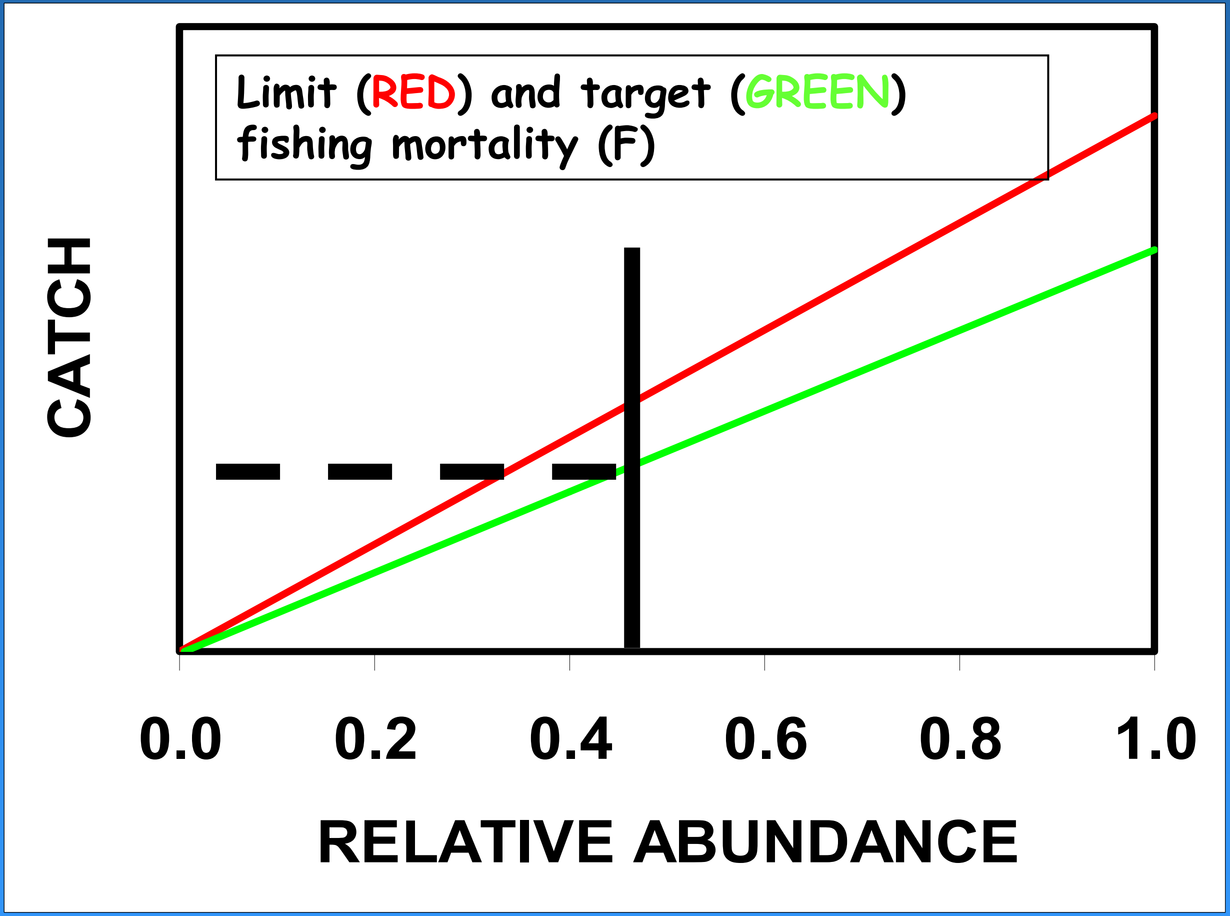


Long-Term Management Advice

- What harvest level (Optimum Yield) would maximize long-term benefits while protecting marine ecosystem?
- When will stock rebuild to its target abundance level?

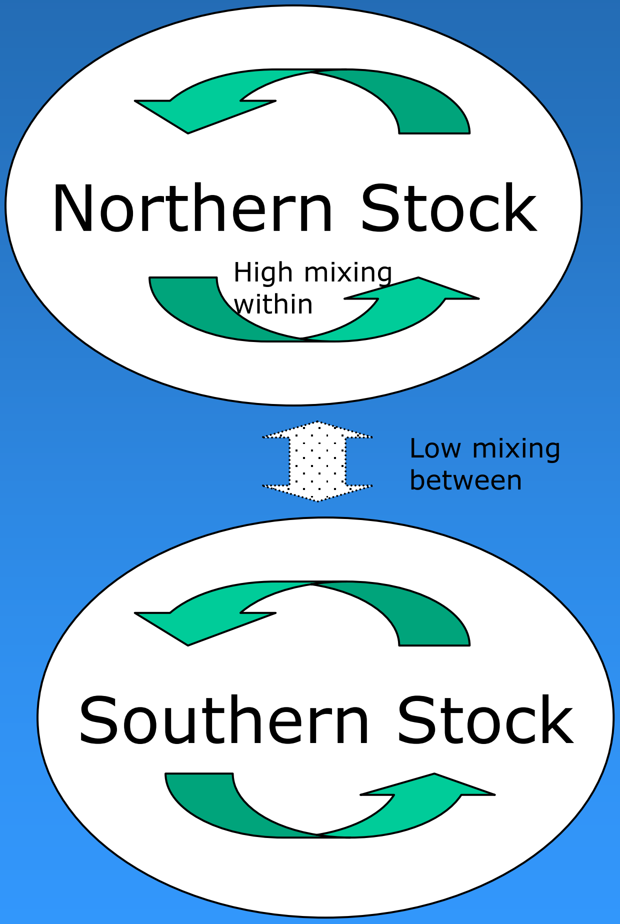
Pro-Active, Short-Term:

What level of catch next year corresponds to the limit and target fishing mortality rate?



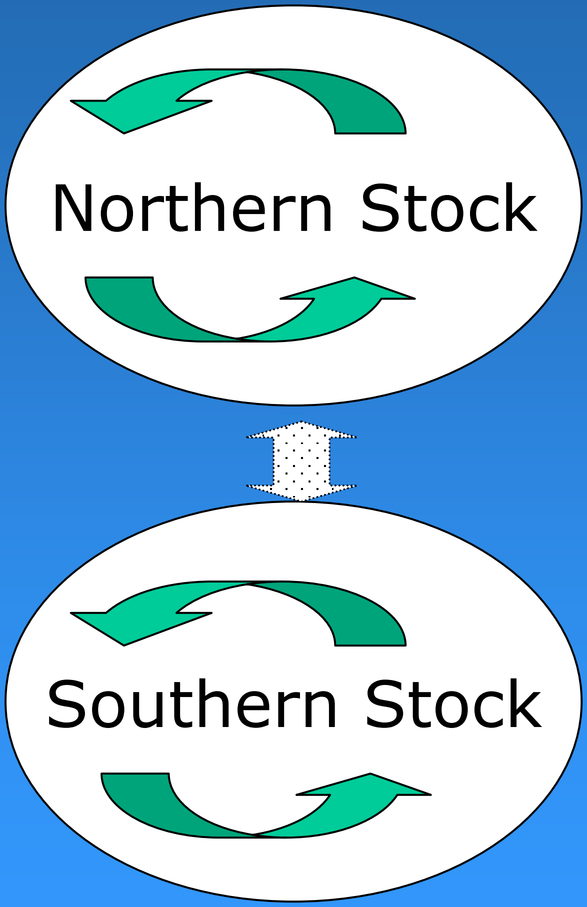
What is a "Stock"?

- A group of individuals of the same species
- That inhabit the same geographic region
- And that interbreed when mature
- Multi-species complex ≠ true biological stock

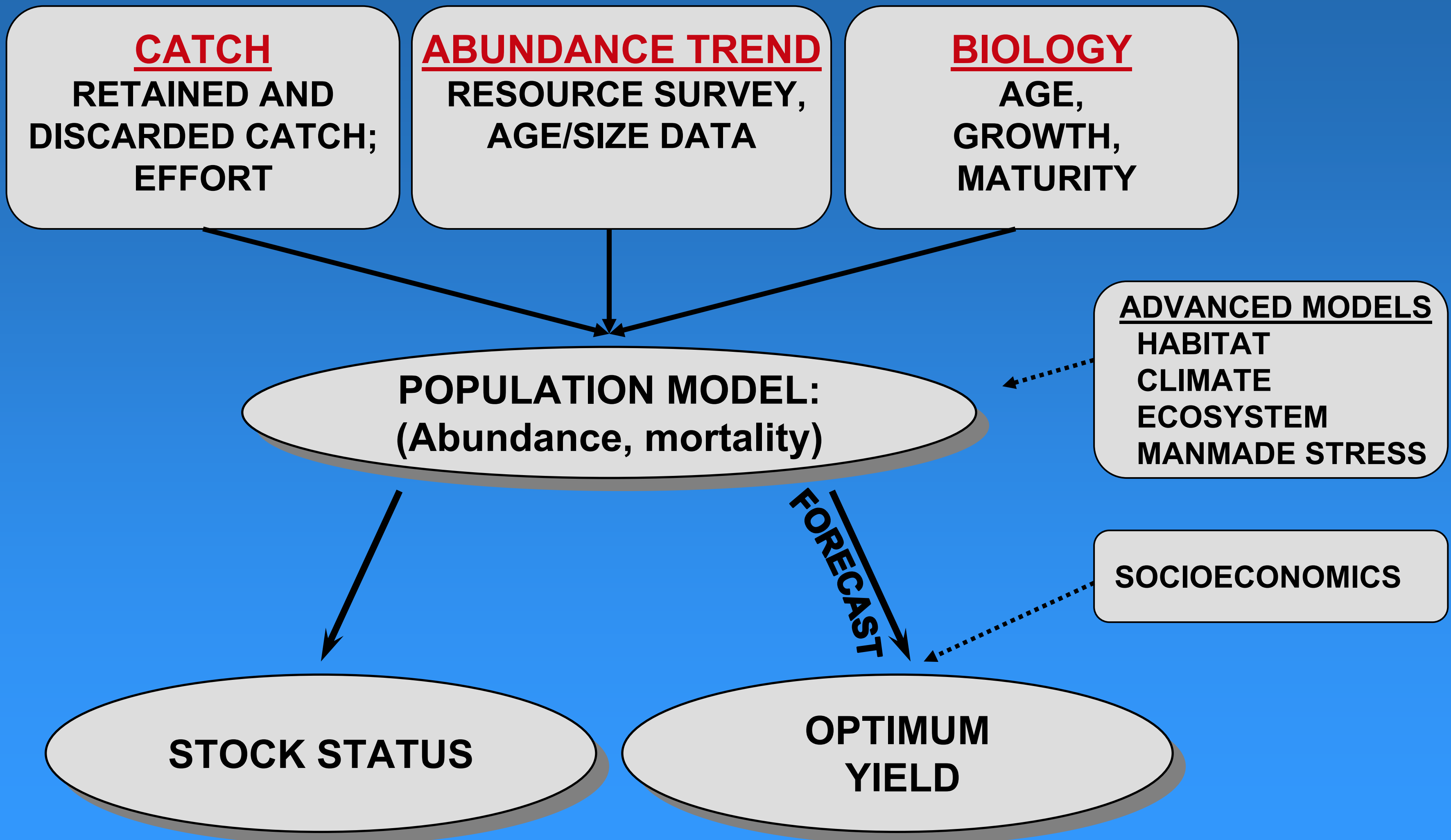


"Stock" Issues

- Assessment models assumes high mixing within stock and negligible mixing between stocks
- Smaller management units guard against localized depletion, but data needs go up
- Larger management unit still needs stock-specific assessments



STOCK ASSESSMENT PROCESS



Catch Data
Fisheries Information System

- Commercial fishing effort, catch, and value
  - Dealer reports
  - Vessel trip reports
- Recreational fishing effort and catch
  - Telephone surveys
  - Shoreside sampling surveys
- Size and age structure of catch
  - Commercial catch sampling surveys
  - Recreational catch sampling surveys
- Electronic dissemination of data
- Serves stock assessment, economic analysis, and fishery monitoring needs

Fishery Observers

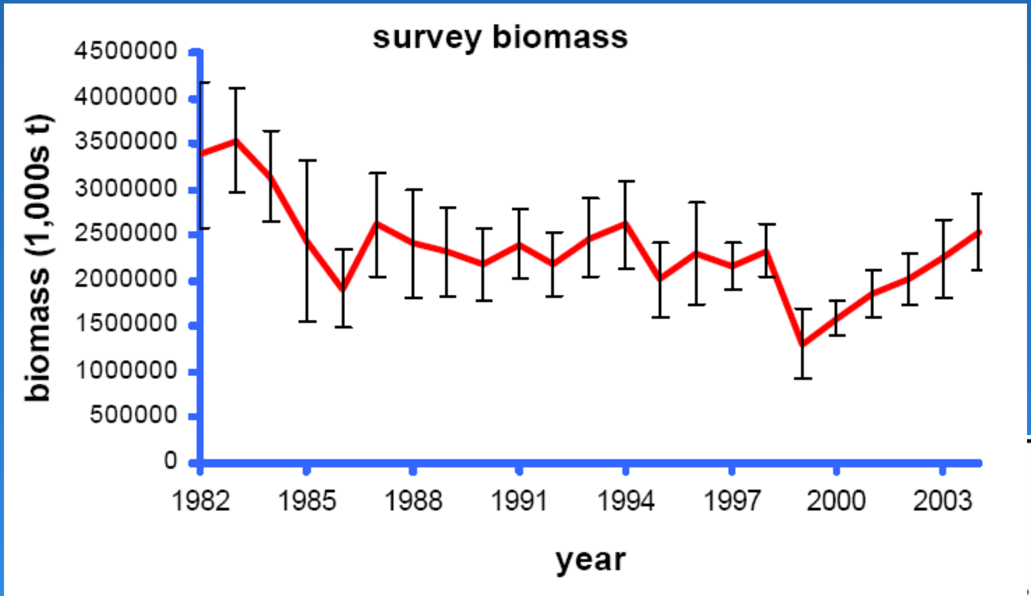
- NOAA Fisheries deploys fishery observers to collect catch and bycatch data from commercial fishing and processing vessels.
  - Annually 42 fisheries are monitored by observer programs logging over 60,000 observer days at sea.
  - NOAA Fisheries has been using observers to collect fisheries data from 1972 to the present.
  - Observers have monitored fishing activities on all US coasts, collecting data for a range of conservation and management issues.

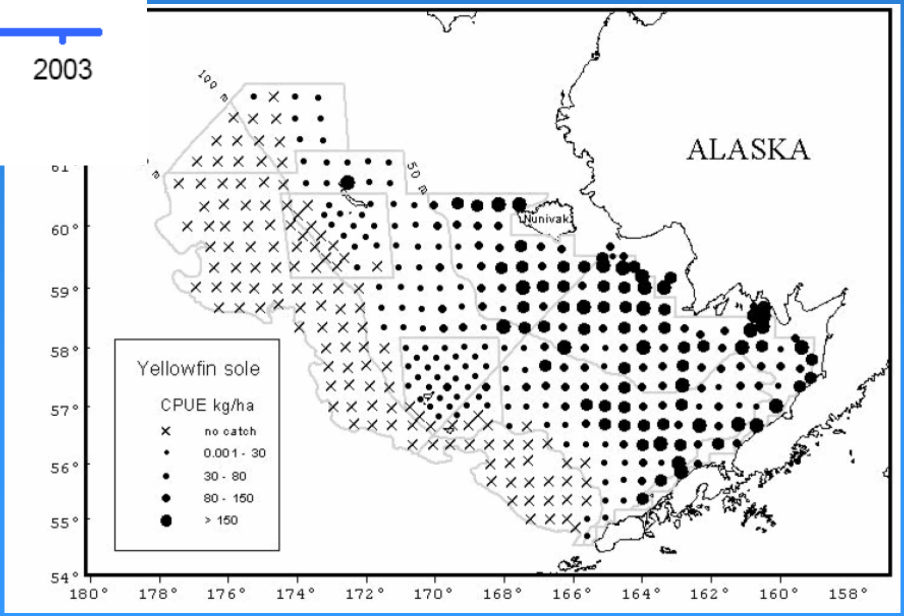
Abundance Index
Fishery-Independent Surveys

- Catch Rate = q x Abundance
- Survey sampling units (effort) is highly standardized;
- Sampling follows a statistical design

- Some survey methods produce relative time series, so information is only in the trend
- Others methods can independently calibrate q so each survey directly estimates abundance

Bering Sea Multispecies Bottom Trawl Survey: yellowfin sole





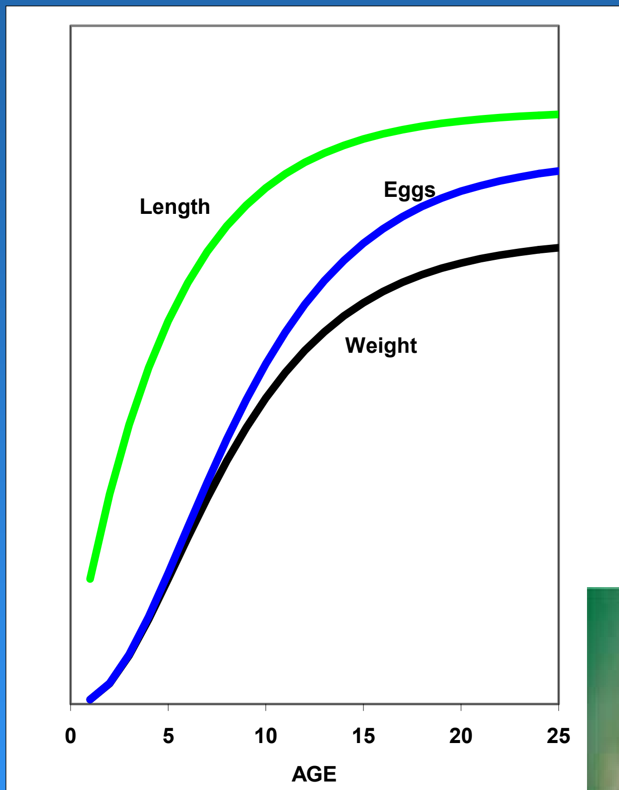
Fishery-Dependent Abundance Index

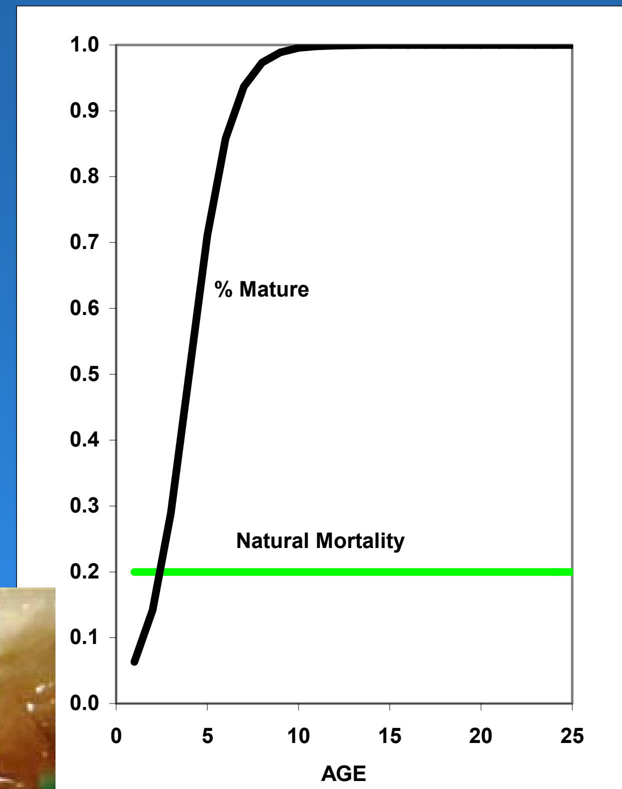
- Fishery Catch Rate (CPUE) should also follow relationship:
  - Catch Rate = q x Abundance
- But q may not be constant because:
  - Fishers don't spread their effort out in a statistical design over the range of the stock
  - Fishing technology changes over time

Advanced Technology

- Autonomous Underwater Vehicle
- Can contain cameras, sensors, acoustics
- Reach into habitats inaccessible to other survey tools

Fish Biology and Life History



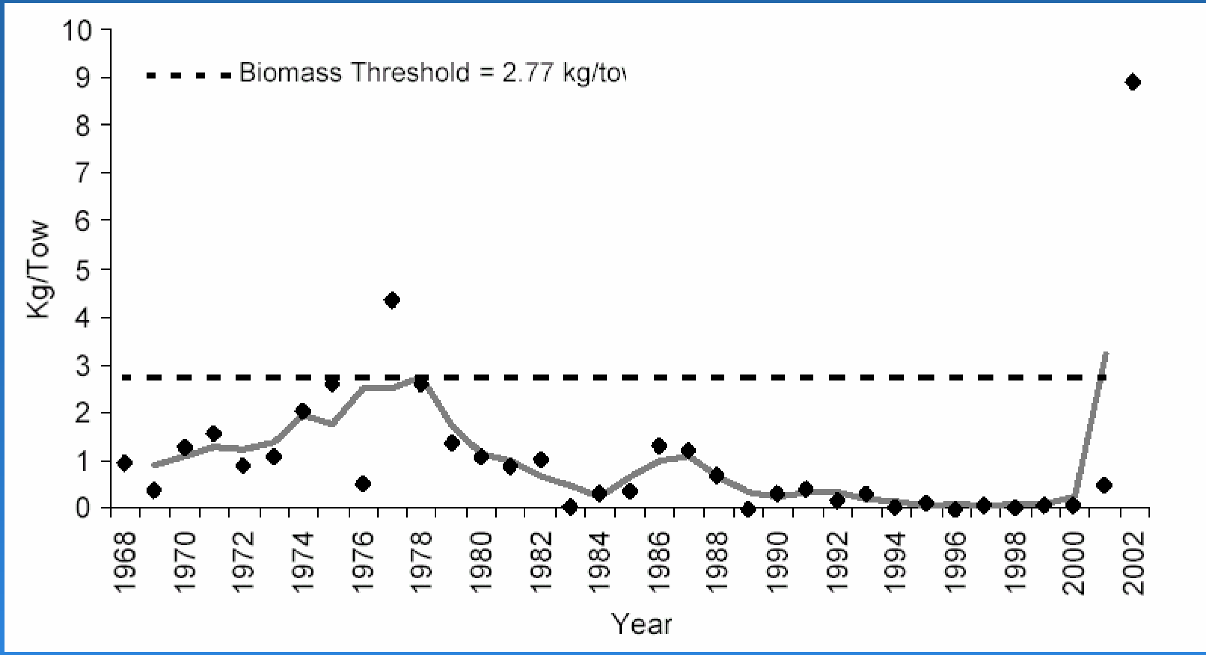


Ease: Length & Weight >> Age > Eggs & Maturity >>> Mortality

Basic Assessment Approaches

- Index Methods
  - Is stock abundance:
    - Increasing, decreasing, or stable?
- Equilibrium Methods
  - On average, is fishing mortality:
    - too high, too low, or just right?
- Dynamic Population Methods
  - Measures stock abundance and mortality
  - Forecast stock abundance and catch level that maintains mortality target
- Choice depends on data availability and complexity of management questions

Index Methods



- Running average of survey or fishery CPUE
- Compare to a benchmark level
- May also compute ratio of catch to index to get relative exploitation rate

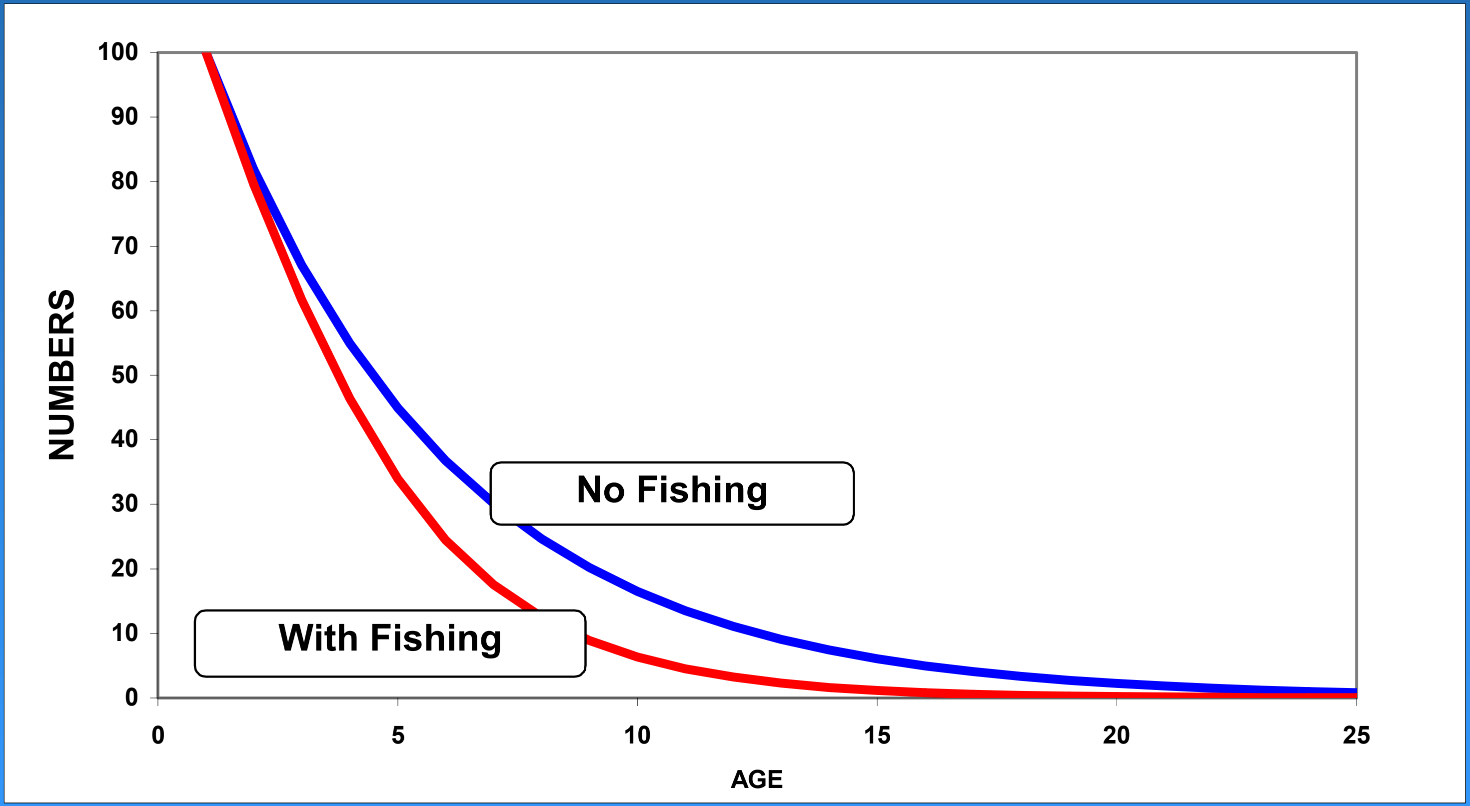
Index Methods: pros & cons

- **Advantages**:
  - Requires only an index of stock size and catch.
  - Able to detect substantial changes in stock size and exploitation.
- **Disadvantages**:
  - Imprecise (large sampling uncertainty)
  - Status can only be related to proxy reference points (e.g., historical averages).
  - Cannot reliably project stock size.
  - Difficult to provide objective management advice.

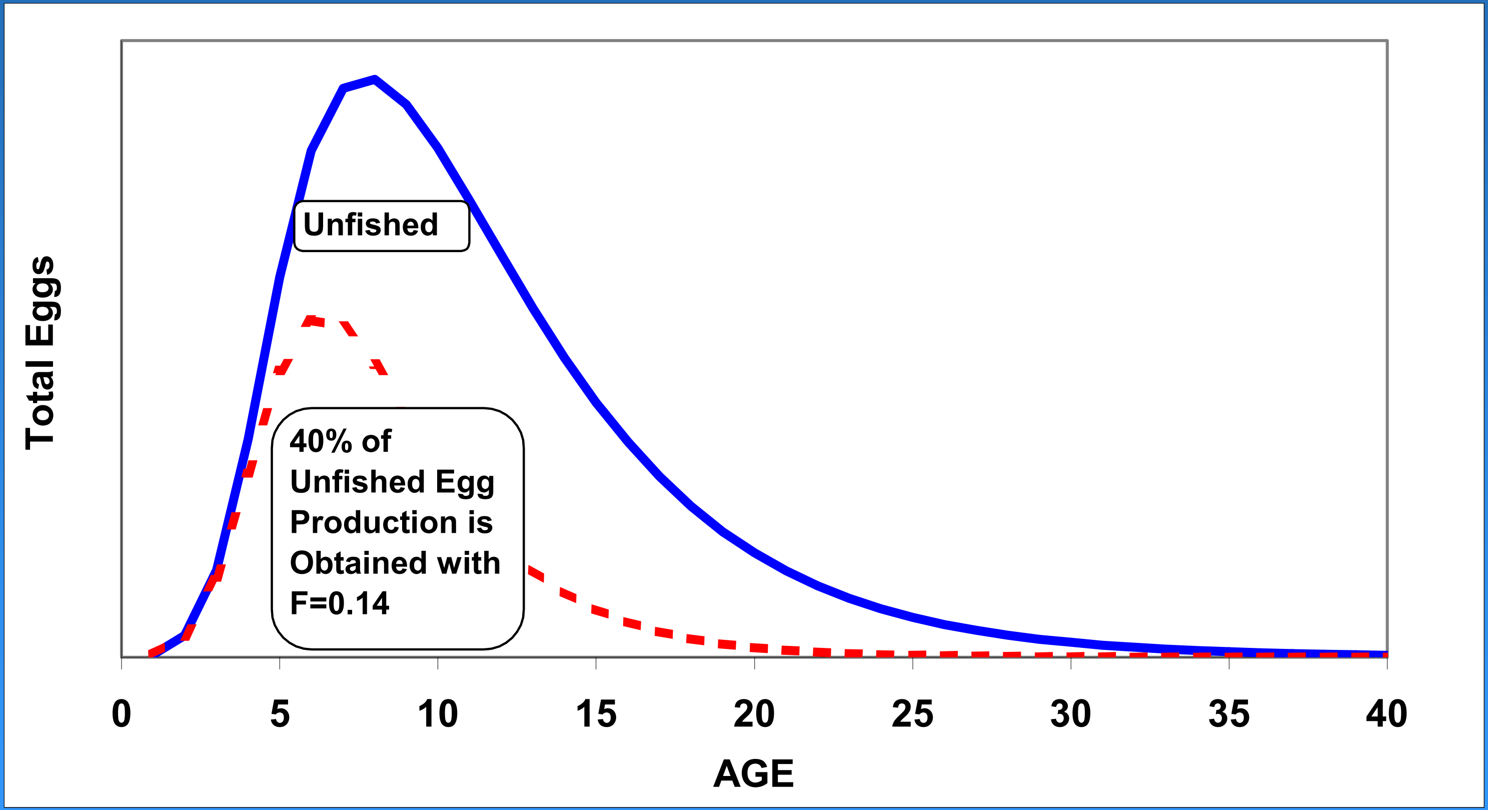
Equilibrium Models Relate Fishing Rates to Effect On Egg Production

- Egg Production commonly indexed by Spawning Biomass
- Spawning Biomass Per Recruit is also known as:
  - SPR
  - Spawning potential ratio
  - Spawners per recruit
  - $F_{xx\%}$
- It is an index of the intensity of the effect of fishing on the reproductive potential of the stock

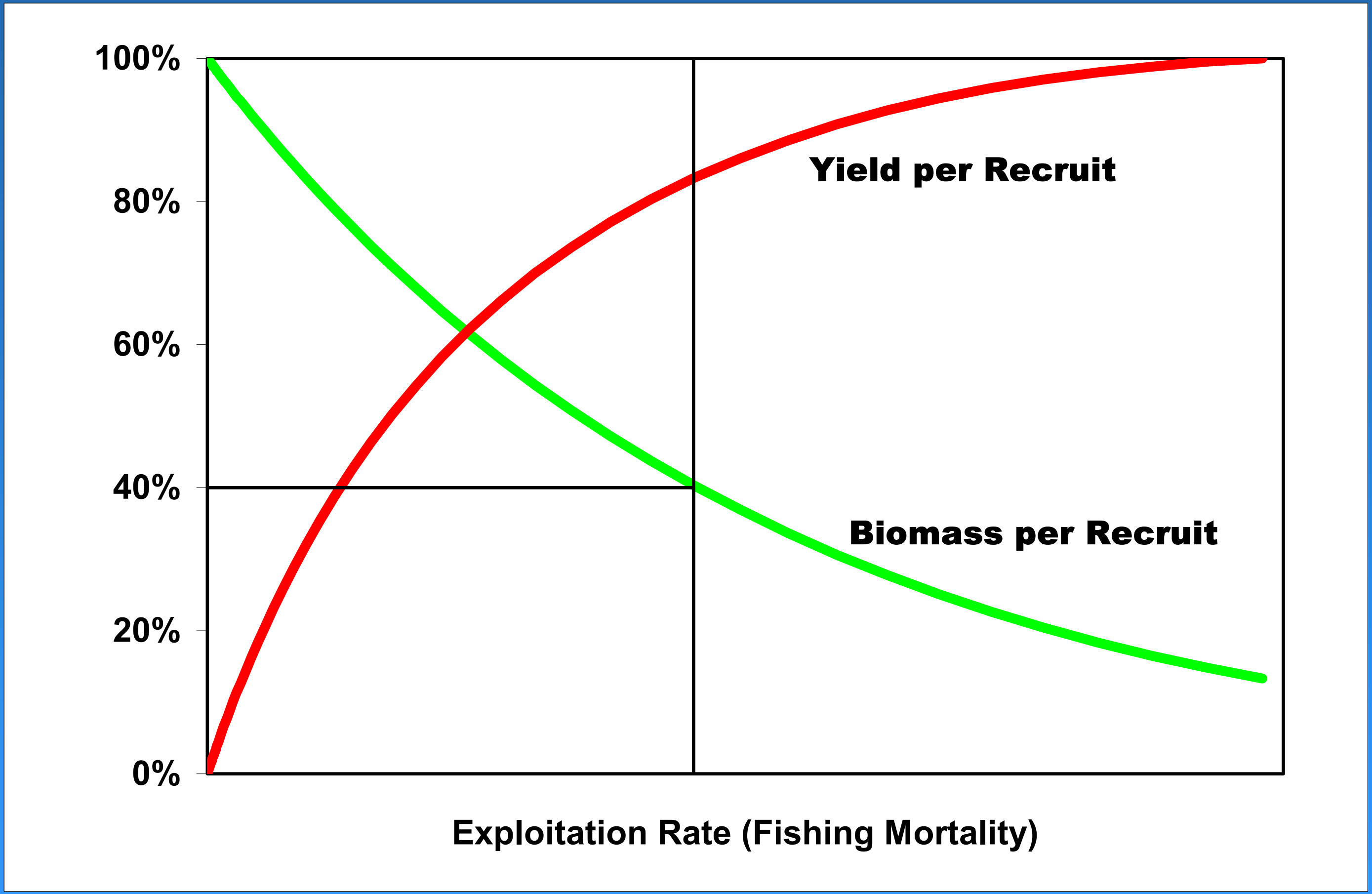
Direct Fishing Effects on Numbers at Age



Egg Production



Fishing Effects on Yield and Eggs (Spawning Biomass) Per Recruit



Equilibrium Methods: Pros & Cons

- **Advantages**:
  - Requires only age or size composition of catch
  - Provides direct information on relative fishing mortality level.
- **Disadvantages**:
  - Highly dependent on model assumptions
  - Status can only be related to proxy reference points
  - Cannot estimate or project abundance
  - Difficult to provide objective management advice.

Stock Productivity

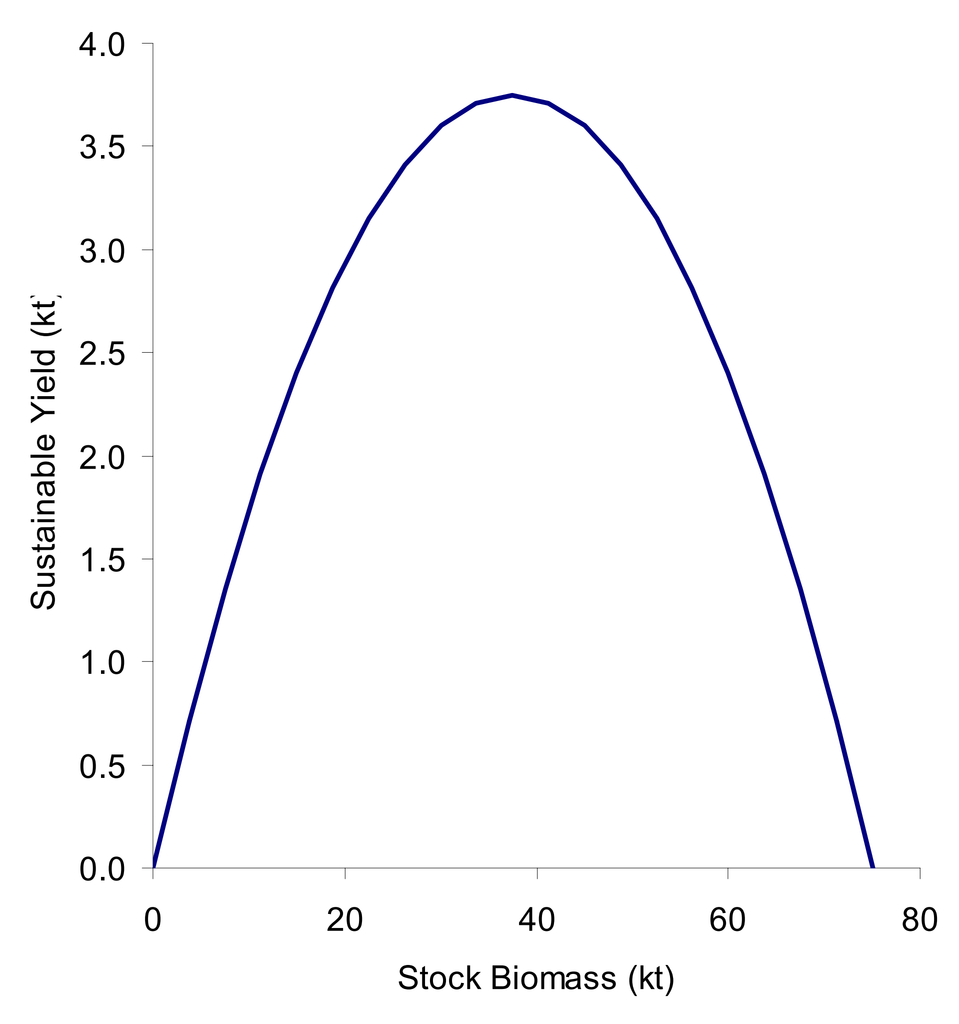
Stock Net Production =

recruitment + growth - natural mortality – catch

- Recruitment: production of eggs & larvae increases as spawner abundance increases, but their survival may decrease with crowding, cannibalism.
- Growth: the sum of individual growth increments increases as stock size increases (more fish -> more population growth)
- Natural mortality: hard to measure changes
- Production Models treat recruitment, growth, and natural mortality as a combined process

Production Model Theory

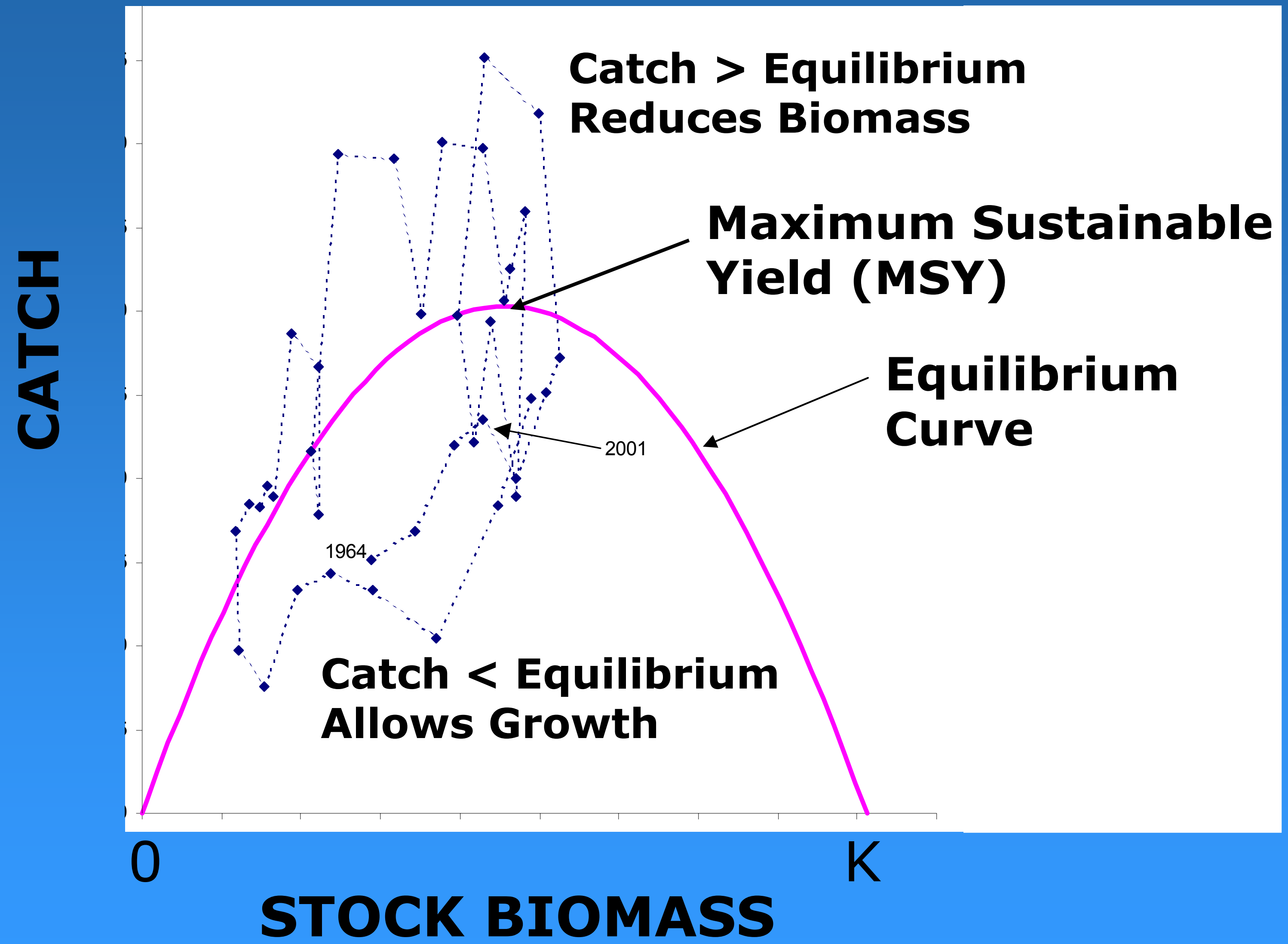
- -Population increase is proportional to its biomass, but the rate of increase slows as the population approaches its carrying capacity.
- -If removals can be replaced by stock production each year, on average, the fishery is sustainable.
- -If stock size is maintained near half its carrying capacity, the population growth rate is fastest, and sustainable yield is greatest (*Maximum Sustainable Yield*).



Logic for Fitting Production Model

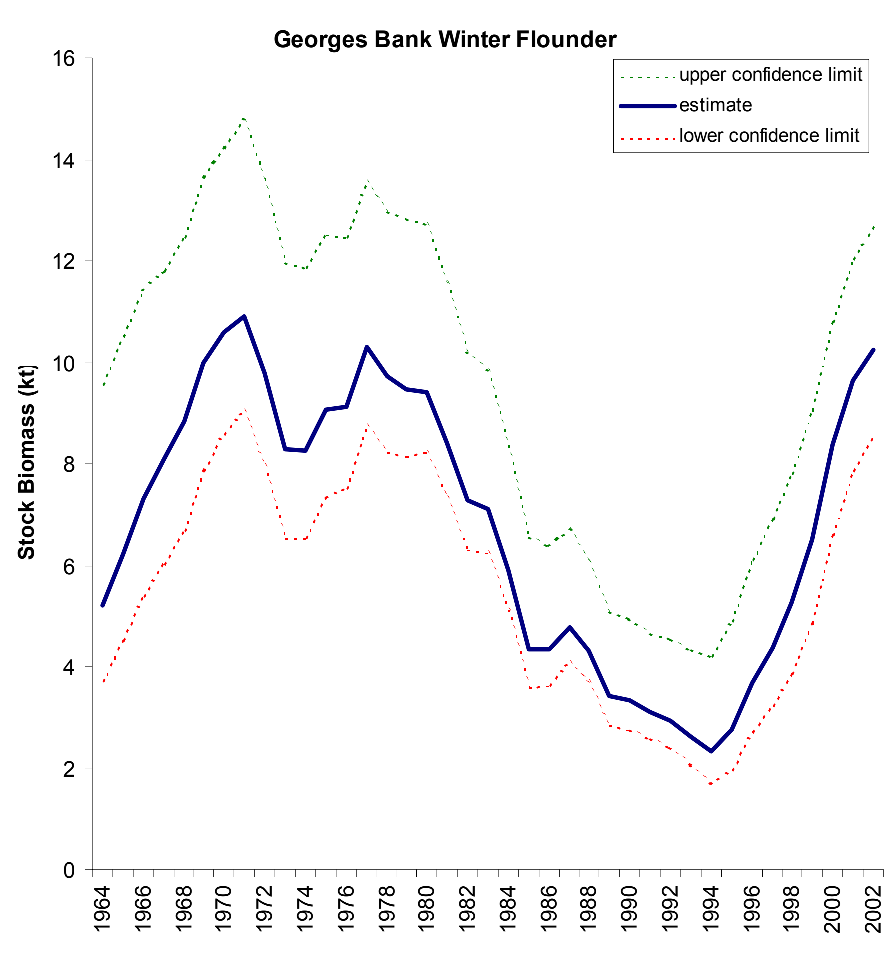
- How big must stock have been if:
  - We saw a relative decline of *X%* per year in the survey index;
  - While *y* tons of catch were removed per year;
  - And the stock's biology indicates that natural changes in abundance are only +/-*Z%* per year?

Production Model



Production Models

- <u>Uncertainty</u>:
  - Disagreements between survey observations and model predictions indicate variability in the data and oversimplification of the model
  - Errors are reshuffled many times to estimate precision "bootstrapping"



Production Models

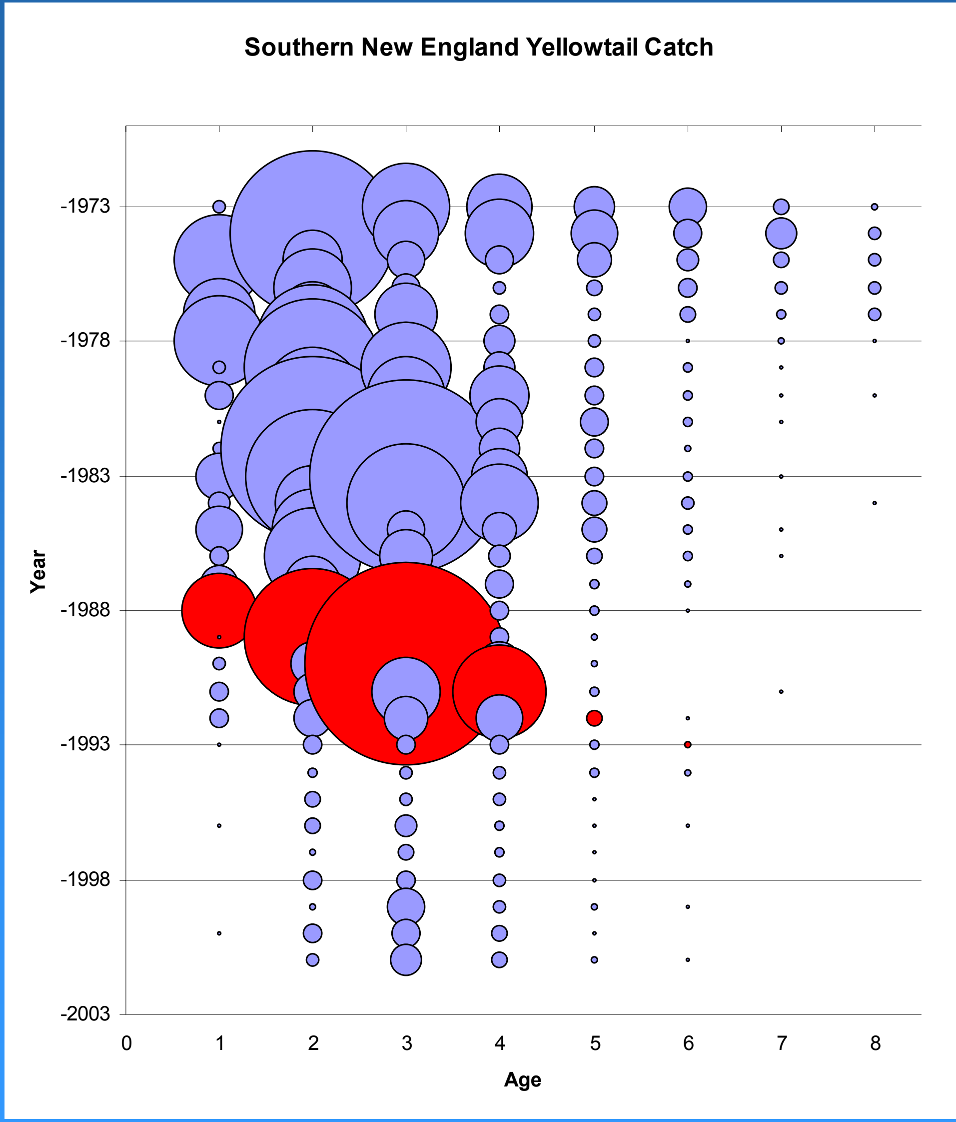
- **Advantages**:
  - Objective determination of stock status.
  - Estimates of Precision.
  - Projections.
  - Does not require intense catch sampling.
- **Disadvantages**:
  - Requires a long time series of accurate catch and reliable survey data – representing a wide range of stock and harvest conditions.
  - Not sensitive to demographic changes (e.g., recruitment events, truncated age structure, immature-mature components).
  - Scaling of absolute estimates may not be reliable.
  - Projections may be biased (no information on incoming recruitment).

Age-Based Dynamic Models

- Age data allow:
  - estimating age-specific fishing mortality
  - Estimating year-to-year fluctuations in recruitment of young fish

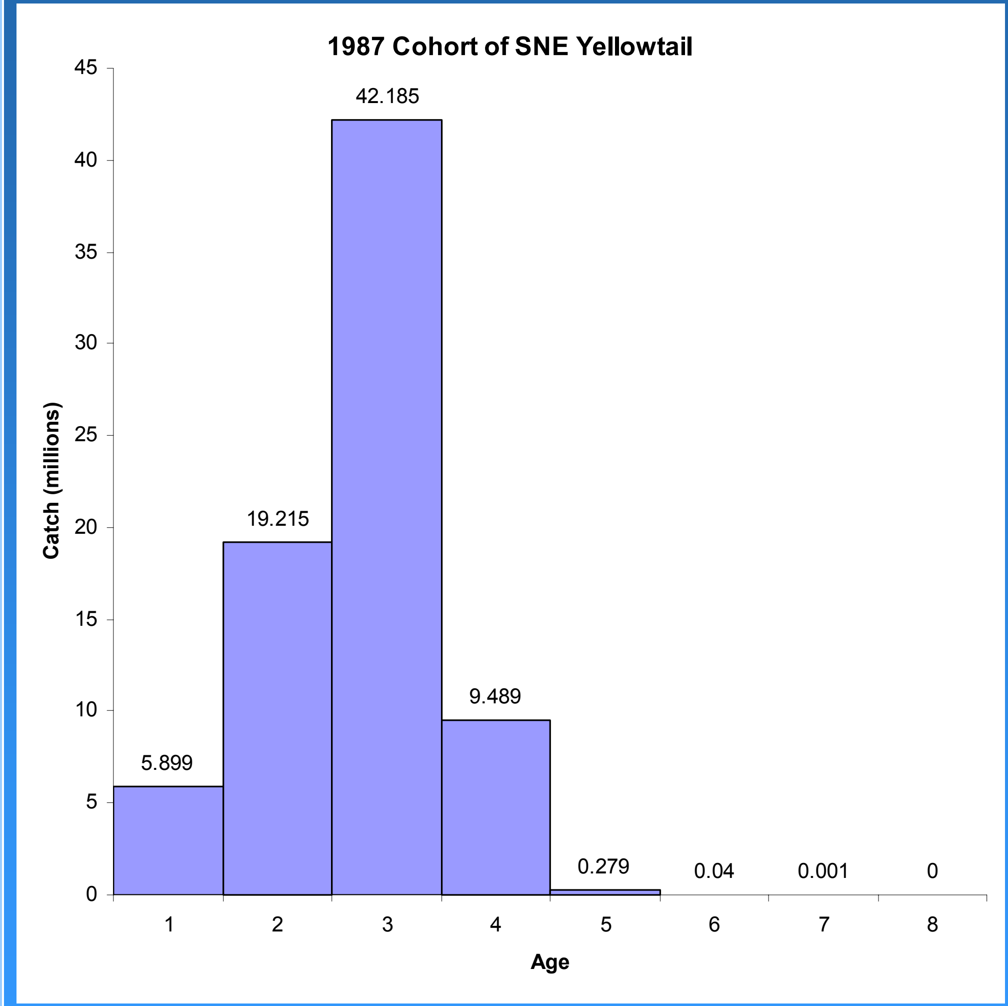
Age-Based Methods

- Age distribution of the catch estimated from census of total catch biomass and port samples.
- Example:
  - F on age 1 declined after 1989
  - Survival to older ages has declined
  - 1987 yearclass dominated the catch in the late 80s early 90s.



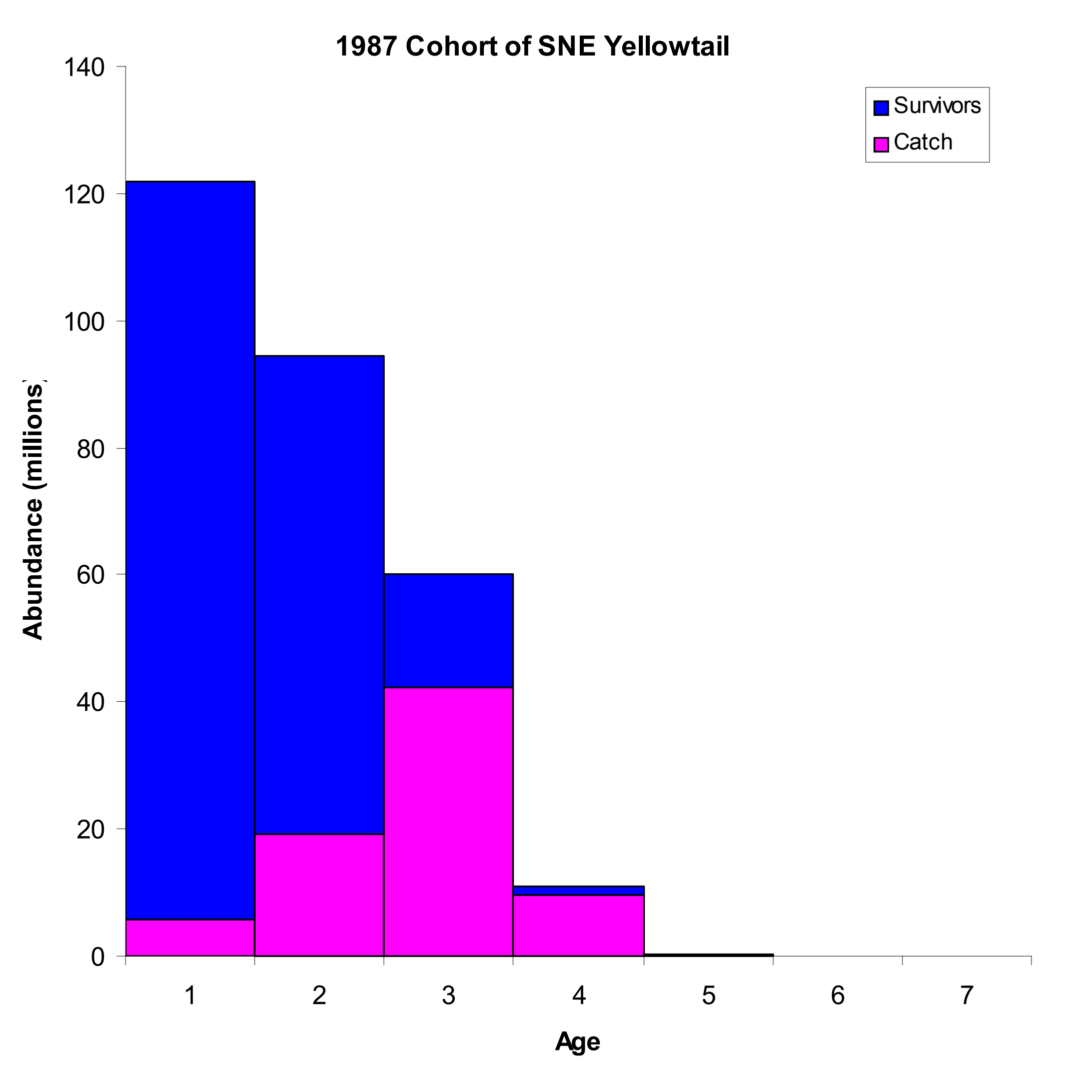
Virtual Population Analysis

- Over the lifespan of the 1987 yearclass, 77 million fish were caught.
- We also know that some fish died from natural mortality.
- So, *at a minimum*, there were 77 million fish when they were 1 year olds.
- But this is just the population we "saw" (*the virtual population*) from the underlying true population.
- *VPA* reconstructs the true population from the virtual population.



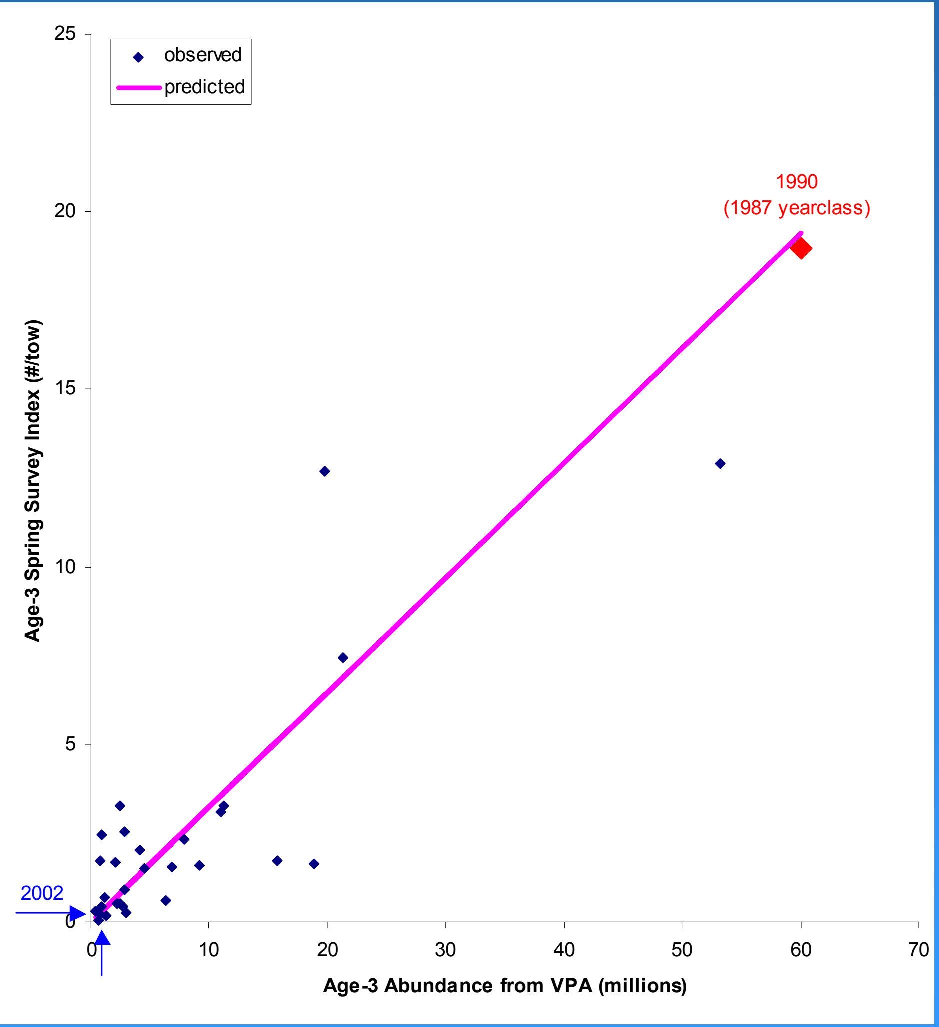
Virtual Population Analysis

- By accounting for observed catch over the lifetime of the cohort (77 million) and natural mortality,
- the age-1 abundance estimate is 122 million.



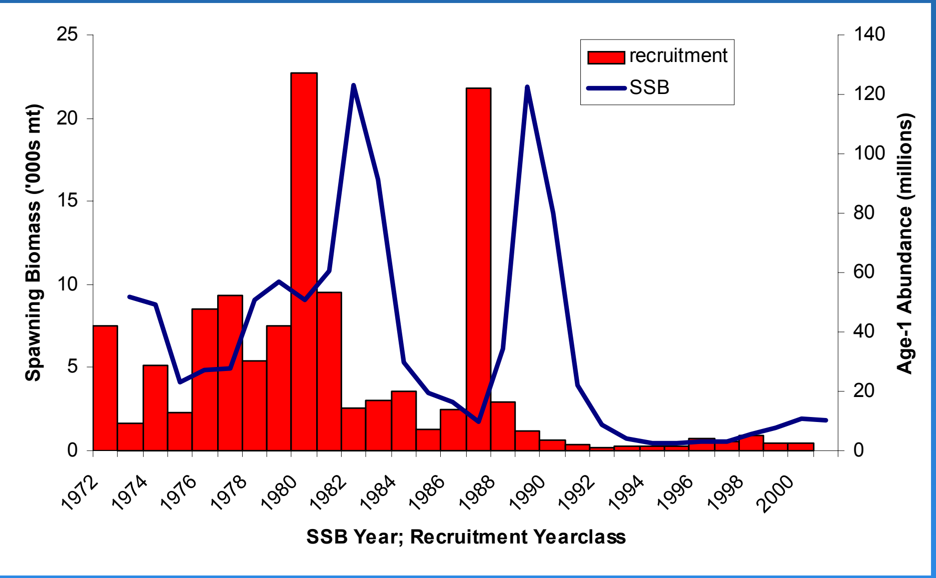
VPA Calibration

- Abundance of living yearclasses in 2002 are estimated using a predictive relationship between historical VPA abundance and survey indices.



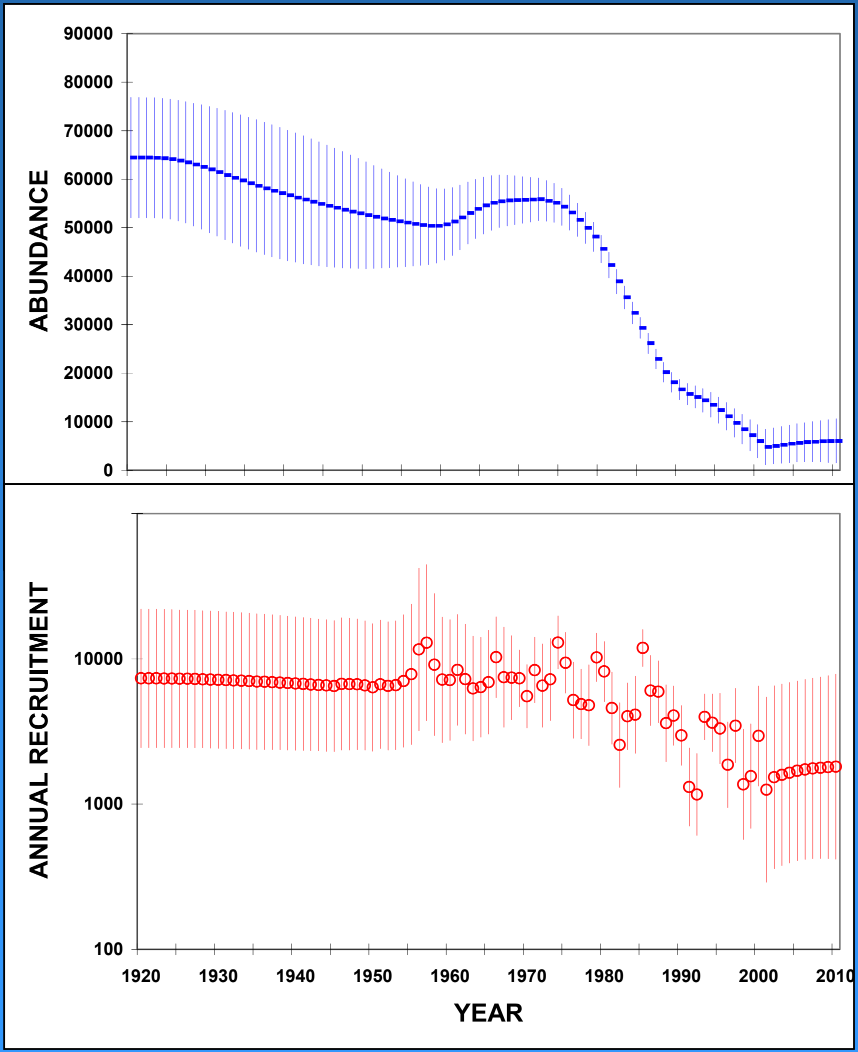
VPA Estimates

- **Informative Assessment:**
  - Example: SNE yellowtail
  - Estimates of stock size and F,
  - But also age distribution, recruitment, mature biomass, etc.



Integrated Analysis

- Age-based internal model
- Able to use various age, length, abundance data to calibrate model
- Smoothly transitions from pre-data era, to data-rich era, to forecast.
- Produces comprehensive estimates of model uncertainty



Age-Based Assessments

- **Advantages:**
  - detailed information about the population (recruitment, age structure, mortality)
  - Age-structure allows non-equilibrium forecasts
- **Disadvantages:**
  - requires accurate catch at age (sampling, ageing)
  - may be a limited time series

Data, Model Choice, Outputs

- Index Method: relative biomass trend only, no F estimate
- Equilibrium Method: average F only, no trend and no biomass
- Production Model: produces trend and absolute level of biomass and F, but lacks detail
- Age-Based Models: Age-based details more accurate if simple assumptions of P.M. are wrong; better forecasting ability

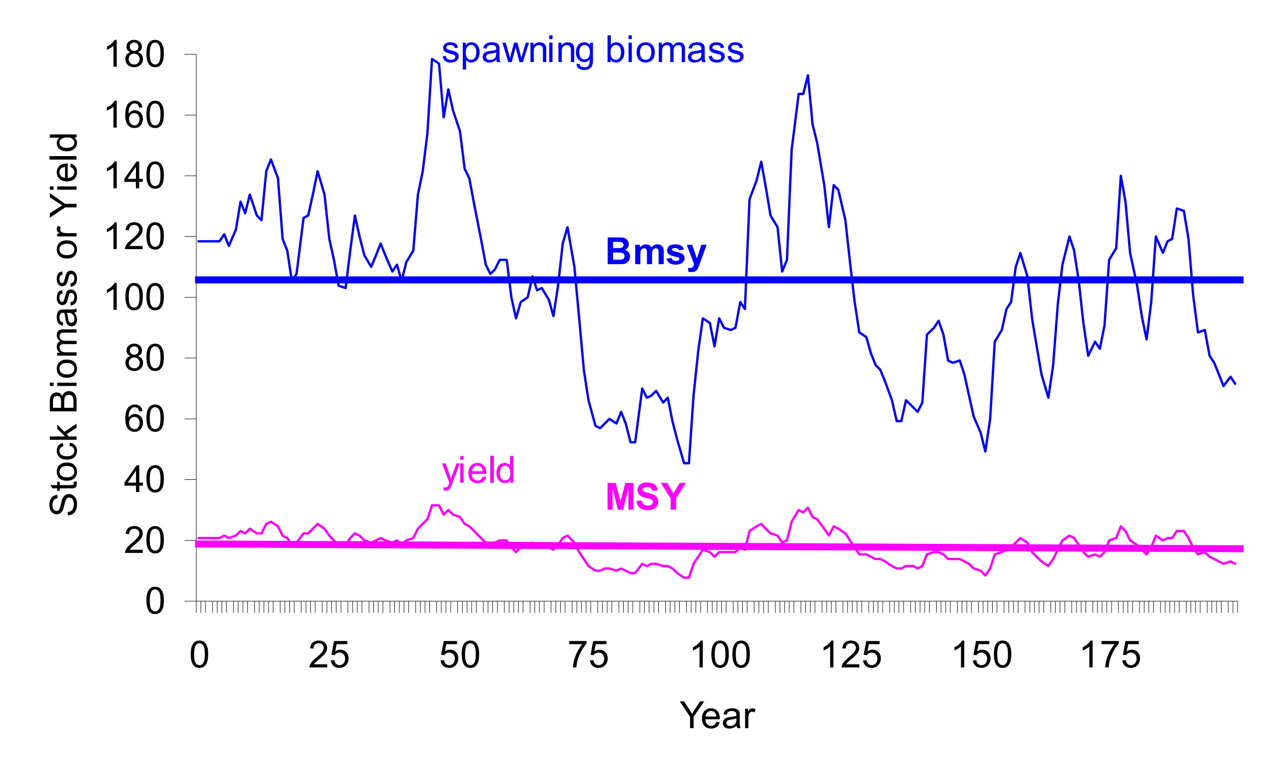
Management Strategy Evaluation (MSE)

- Computer-intensive test of assessment and management performance
  - Simulate biology of stock
  - Generate estimate of index, including variability
  - Calculate management reaction to index (control rule), including time lags
  - Calculate response of stock to management
  - Repeat many times
- What kinds of index work best?
- What kinds of control rules work best?

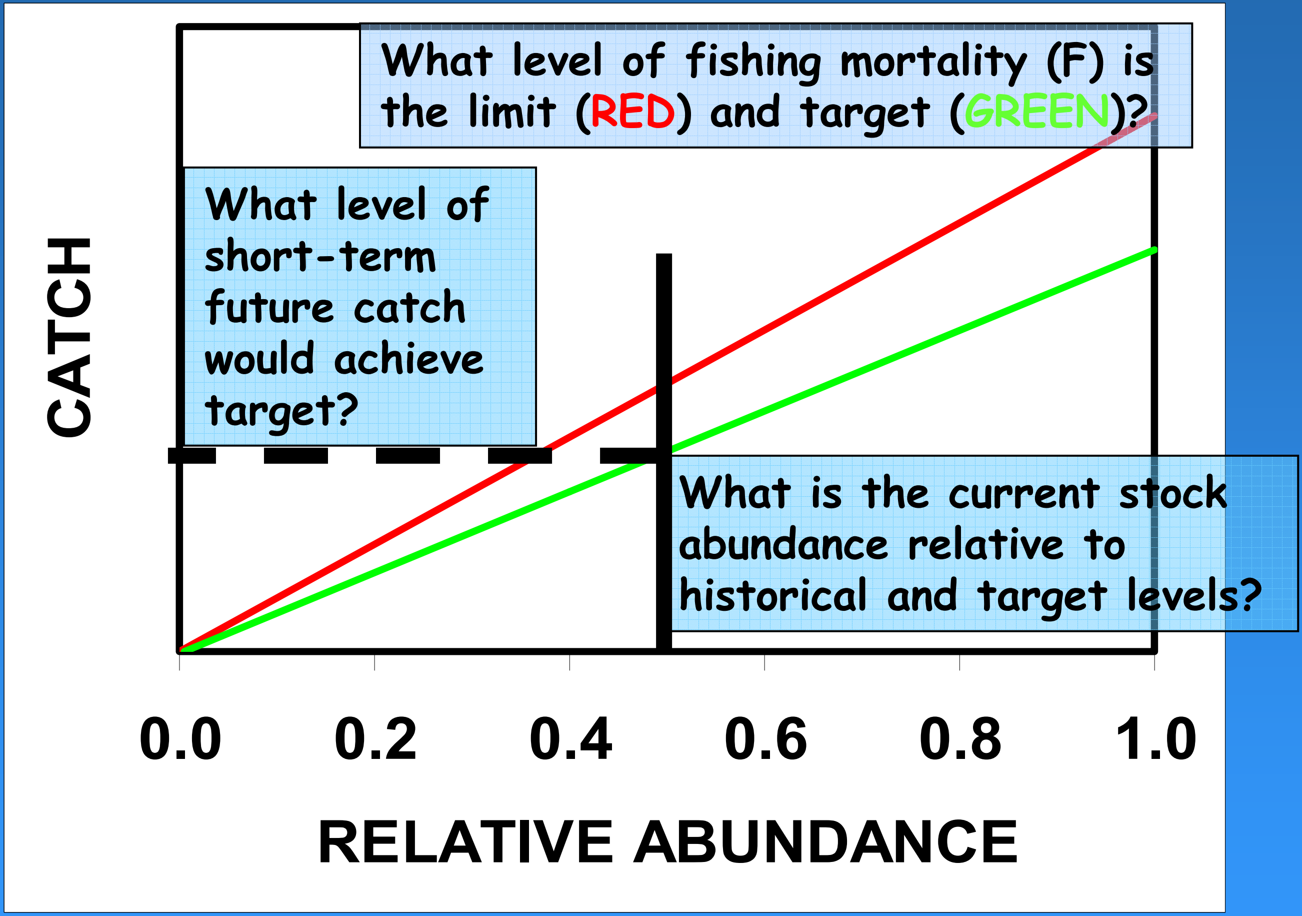
MSY and ABC

- Fmsy: Fishing mortality that yields maximum average yield over the long term.
- MSY and Bmsy are emergent properties of fishing at Fmsy:
  - Annual catch at Fmsy is the ABC (Acceptable Biological Catch)
  - MSY is then the long-term result of fishing at Fmsy.
  - Bmsy the average stock biomass that results from fishing at Fmsy.

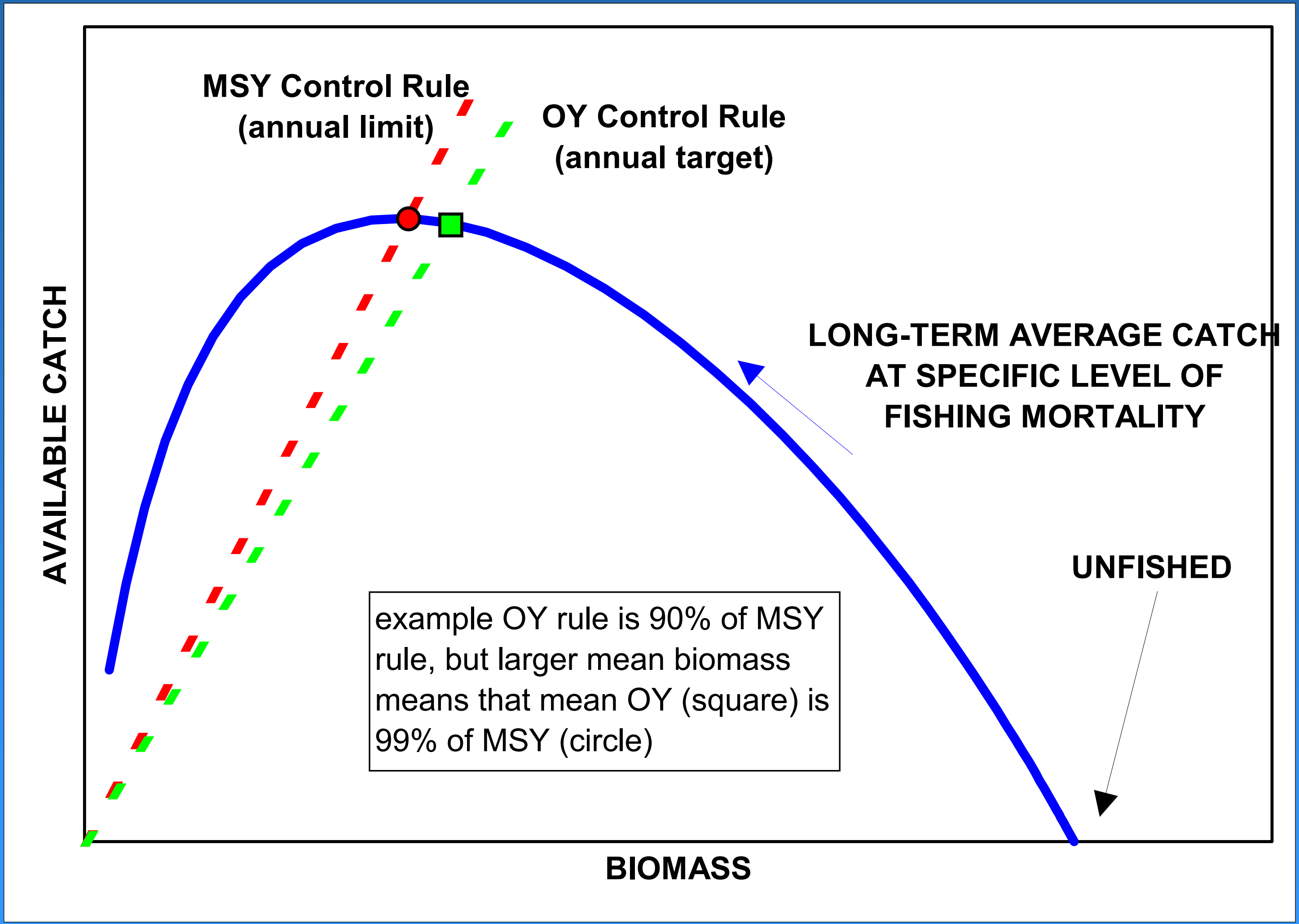
- **Implementation:**
  - **forecast next year's abundance and yield to adjust the Quota, or**
  - **have very good control on the real, effective fishing effort so that the fishing mortality does not change as the stock fluctuates in abundance.**



Harvest Control Rule



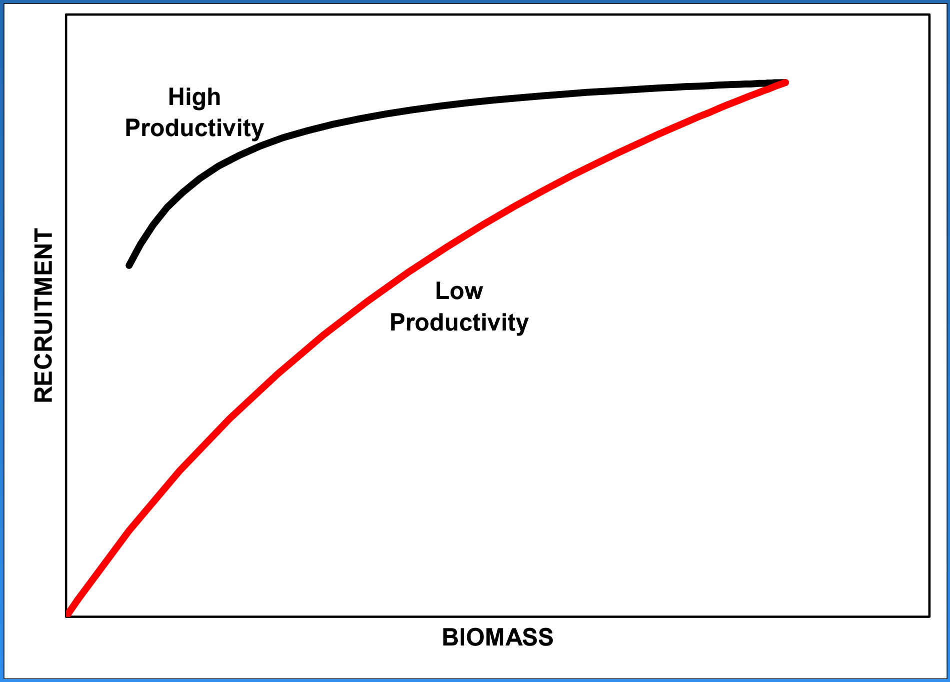
Long-Term Result of Control Rule



*asymmetric curve due to spawner-recruitment model, rather than simple production model

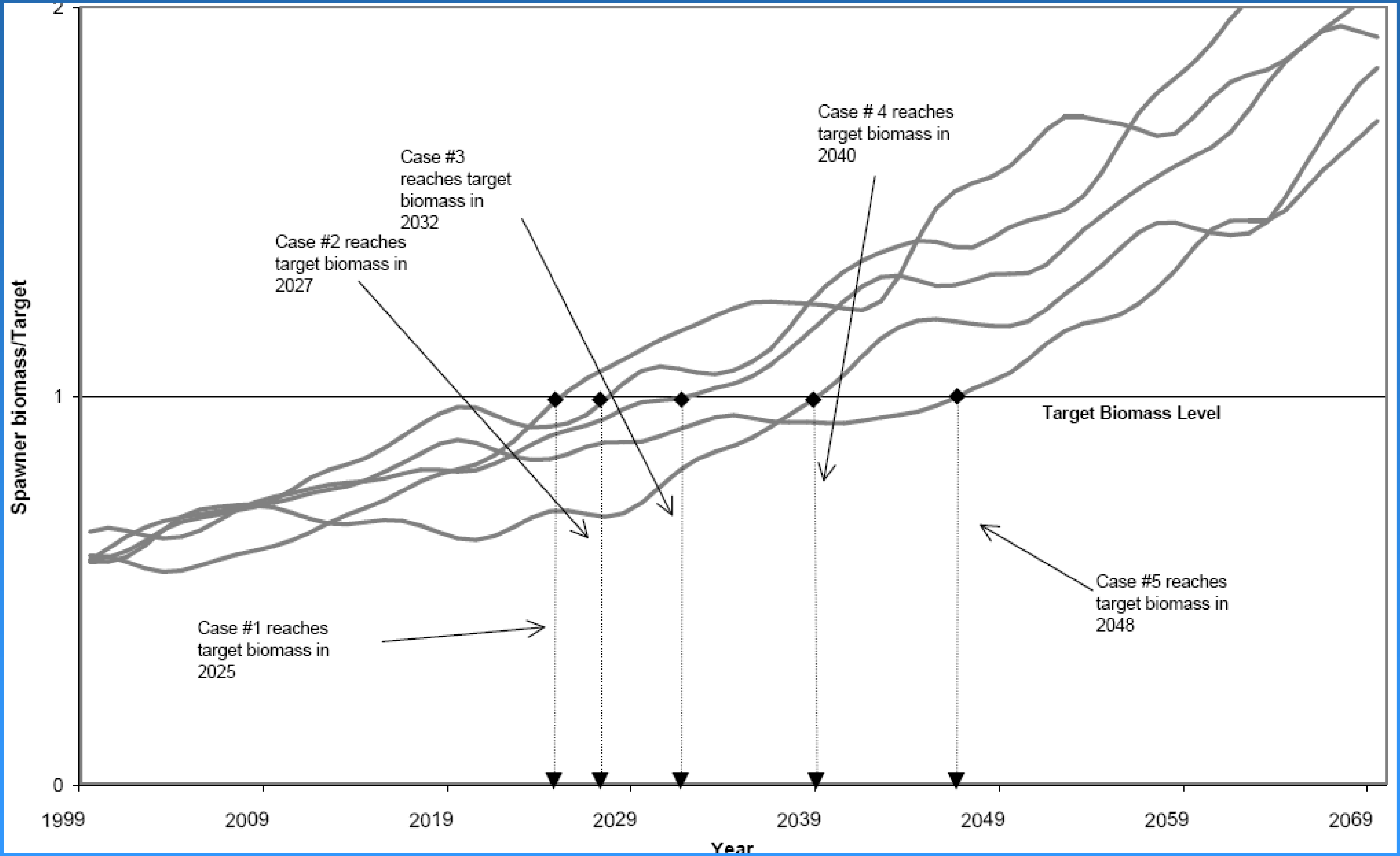
Rebuilding Time Depends on Stock Productivity

High productivity stocks maintain high recruitment levels even as stock abundance declines (e.g. some New England groundfish). They rebuild quickly as fishing mortality is reduced.

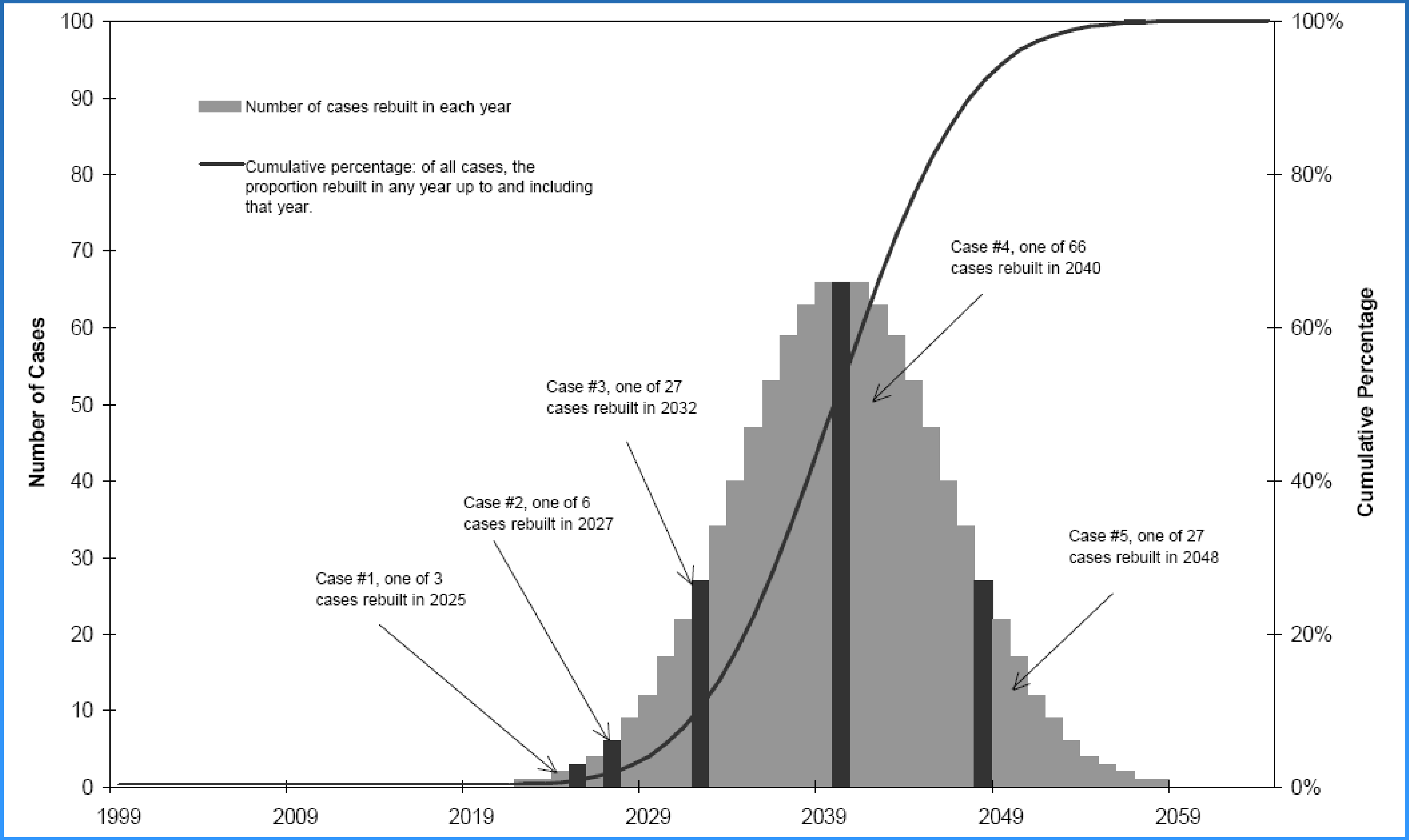


Low productivity stocks can sustain only low fishing mortality rates and, if severely depleted, require multiple generations to rebuild even with minimal fishing mortality (e.g. west coast groundfish).

Rebuilding Projections Based on Probability Distribution of Forecasts

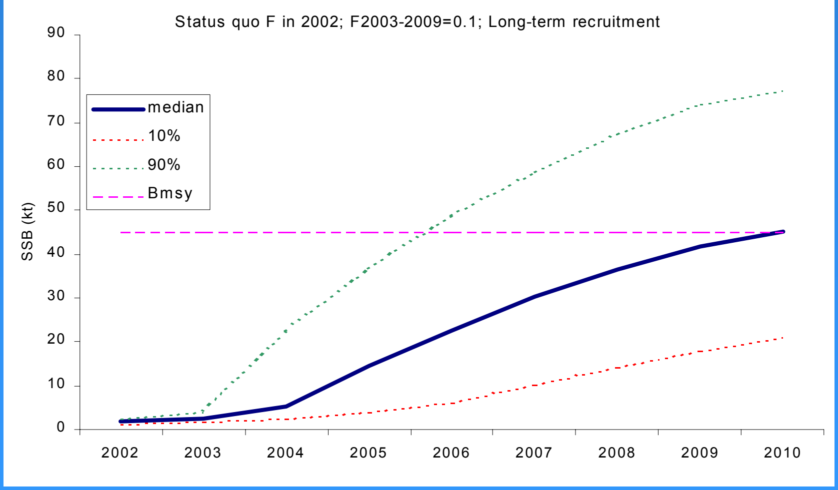


Probability Distribution for Rebuilding



Rebuilding Forecasts

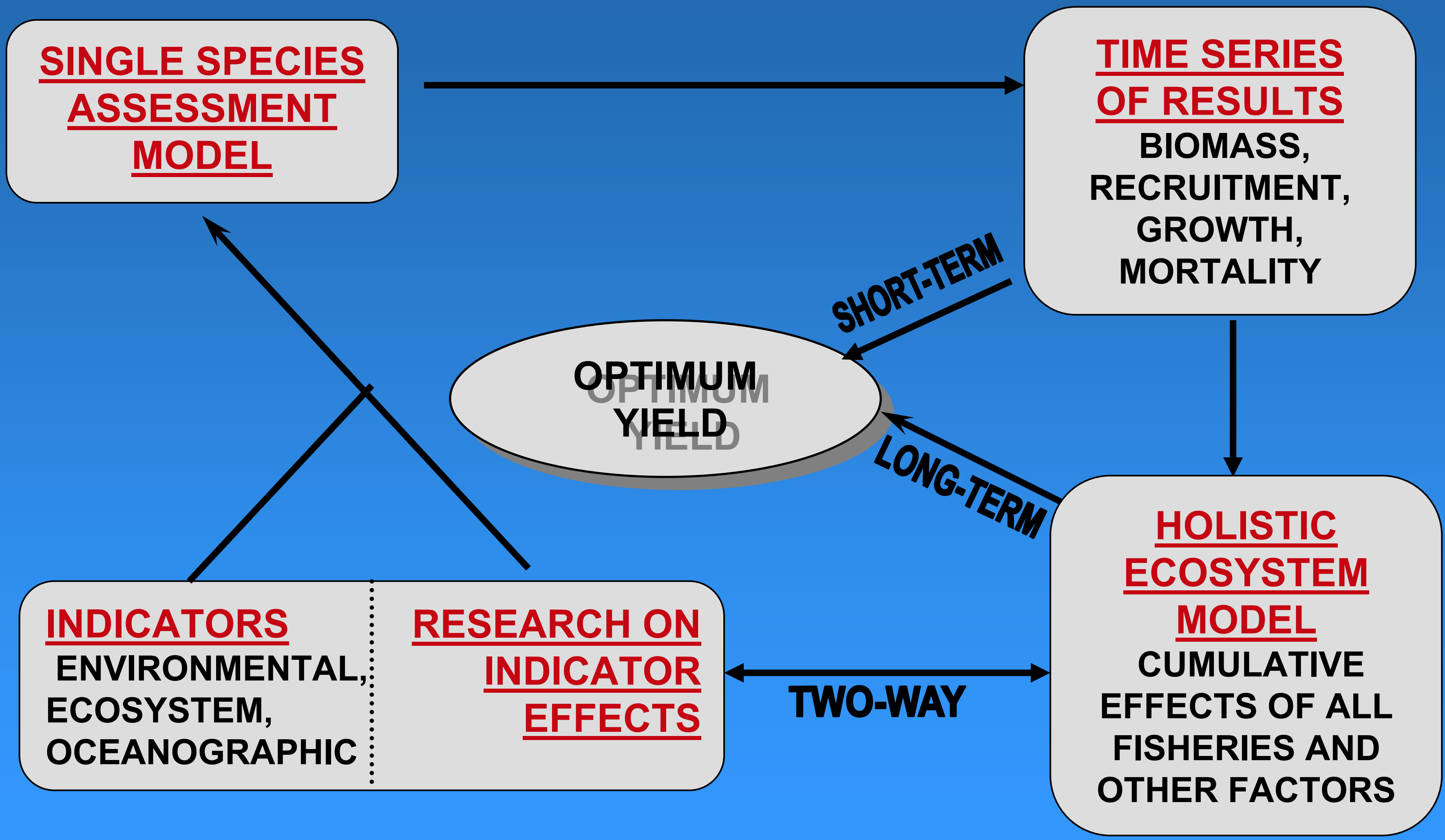
- Two SNE Yellowtail Scenarios
  - Recruitment from the last 10 years and F=0
  - Recruitment from the last 30 years and F=0.1



Stock Assessment Limitations

- With accurate total catch, survey trend in abundance, and biological data, assessments can estimate stock status parameters
- Variable and/or biased data affect results
- Many factors held constant:
  - natural mortality, growth, productivity
  - Overall results appear more precise than they really are, especially with simple models
- Causes of non-fishery changes are outside of knowledge base and models

Stock Assessment – Ecosystem Connection



ASSESSMENT SUMMARY

- Assessments are designed to answer management questions
- Variety of methods tuned to diverse data availability scenarios
- Assessments produce estimates of stock abundance, mortality and productivity
- Forecasts provide probability distribution of future stock conditions and yield under hypothesized harvest scenarios